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LODGEPOLE PINE MANAGEMENT IN THE INTERMOUNTAIN REGION

A PROBLEM ANALYSIS

by
DAVID TACKLE

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION

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A PROBLEM ANALYSIS

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Foreword

In 1952 the Experiment Station in cooperation with Region 4 of the Forest Service initiated a study to determine the status of lodgepole pine management in the Intermountain region. This report presents and analyzes the problems in managing lodgepole pine as disclosed by the study. It also suggests a research program to solve some of the more important problems.

In addition to the silvicultural aspects of lodgepole pine management the silvical relations are discussed and analyzed. Considerable attention is given to the economic factors that limit utilization; the effects of the degree of utilization on silvicultural practices are also interpreted. The importance of adequate inventories is explained, as well as some of the important mensurational problems that require investigation.

Because some 90 percent of the Intermountain region's lodgepole pine lands are administered by the Forest Service, emphasis is placed on timber management problems that occur on the national forests. Suggestions for solving these problems, however, should be adaptable to corresponding needs on lands outside the national forests.

REED W. BAILEY, Director
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LODGEPOLE PINE MANAGEMENT IN THE INTERMOUNTAIN REGION

A PROBLEM ANALYSIS

Introduction

There are more than 4 million acres of lodgepole pine (Pinus contorta Dougl.) forest land supporting some 2.5 billion board feet of sawtimber in the Intermountain region.[1/, 2/] Although trees have been harvested from these forests for more than half a century there is still uncertainty about the way lodgepole stands should be managed. The need for some form of investigative effort to attack forest management problems in the lodgepole type in this region has been generally accepted and confirmed (67, 68).[3/] Recommendations for research in this species have been stated in general terms (19, 46), but no specific program has been set forth.

The purpose of this problem analysis is, therefore, to present a sound approach to a specific program covering all the major phases of forest management research in lodgepole pine within the Intermountain region. This analysis is based upon a complete and thorough review of previous work and current investigations elsewhere, and an intensive, orderly appraisal of problems inherent to Region 4, gauged by field observations and interviews with administrative personnel on the Ashley, Boise, Bridger, Cache, Caribou, Challis, Payette, Salmon, Sawtooth, Targhee, Teton, Uinta, and Wasatch National Forests. It is presented in four parts:

Part I. Physical, economic, and social relationships of lodgepole pine forests to the Intermountain region.

Part II. Lodgepole pine management problems and their general implications in management.

Part III. Evaluation of problems and proposals for their solution.

Part IV. Suggested research program.

1/ Region 4 in the U. S. Forest Service numerical classification of administrative regions.

2/ Area and volume figures from Revised Timber and Area Estimates--1945. Regional Office, Region 4, Ogden, Utah.

3/ Numbers in parentheses refer to literature cited, page 47.

PART I

THE INTERMOUNTAIN REGION AND ITS LODGEPOLE FORESTS

Physical Aspects

Geographic extent.--The Intermountain region embraces the entire State of Utah; Idaho, south of the Salmon River; Nevada (except a small area in the west-central part); western Wyoming; and small parts of east-central California and western Colorado (fig. 1). It is an area comprising 176,647,000 acres of land.

The lodgepole pine forests occur almost entirely in the extreme northern, northeastern, and east-central parts of the region (fig. 2).

Physiographic features.--The region has wide extremes of topography and elevation, for within it are included parts of several main mountain systems and plateaus. In the west rises the Sierra Nevada, in the northeast are the Rocky Mountains, in the north and southeast are the Columbia and Colorado Plateaus respectively, and in the southwest lies the Sonoran Desert.

Much of the land lies at 4,000 to 5,000 feet above sea level, although the southern tip of Nevada along the Colorado River is only some 500 feet above sea level, the lowest point in the region. Mountains reach an elevation above sea level of from 7,000 to 13,000 feet.

Most of Nevada and nearly the entire western half of Utah have an interior drainage pattern, with numerous north-south mountain ranges and many small basins. The Idaho part of the region is included principally within the Columbia River drainage system, and most of the Wyoming and eastern and southern Utah portions lie within the Colorado River drainage.

Climate.--Because of its extreme variations in topography and elevation the region shows considerable climatic variation from one locality to another. Precipitation in the lower valleys and basins generally averages less than 15 inches annually. Some desert areas receive as few as 4 inches of precipitation annually.

Precipitation in the mountains, mostly in the form of snow, usually increases with altitude and estimates based on snow course measurements indicate a maximum precipitation of 60 inches in the highest elevations.

Temperatures also vary with elevation and location. Normally temperatures range from about 100° F. to a few degrees below zero, but records indicate extremes of 120° F. above to 52° F. below zero.

In the lodgepole forests precipitation is also variable, one-third to one-half coming during the period April to September. It averages between 16 and 30 inches annually.

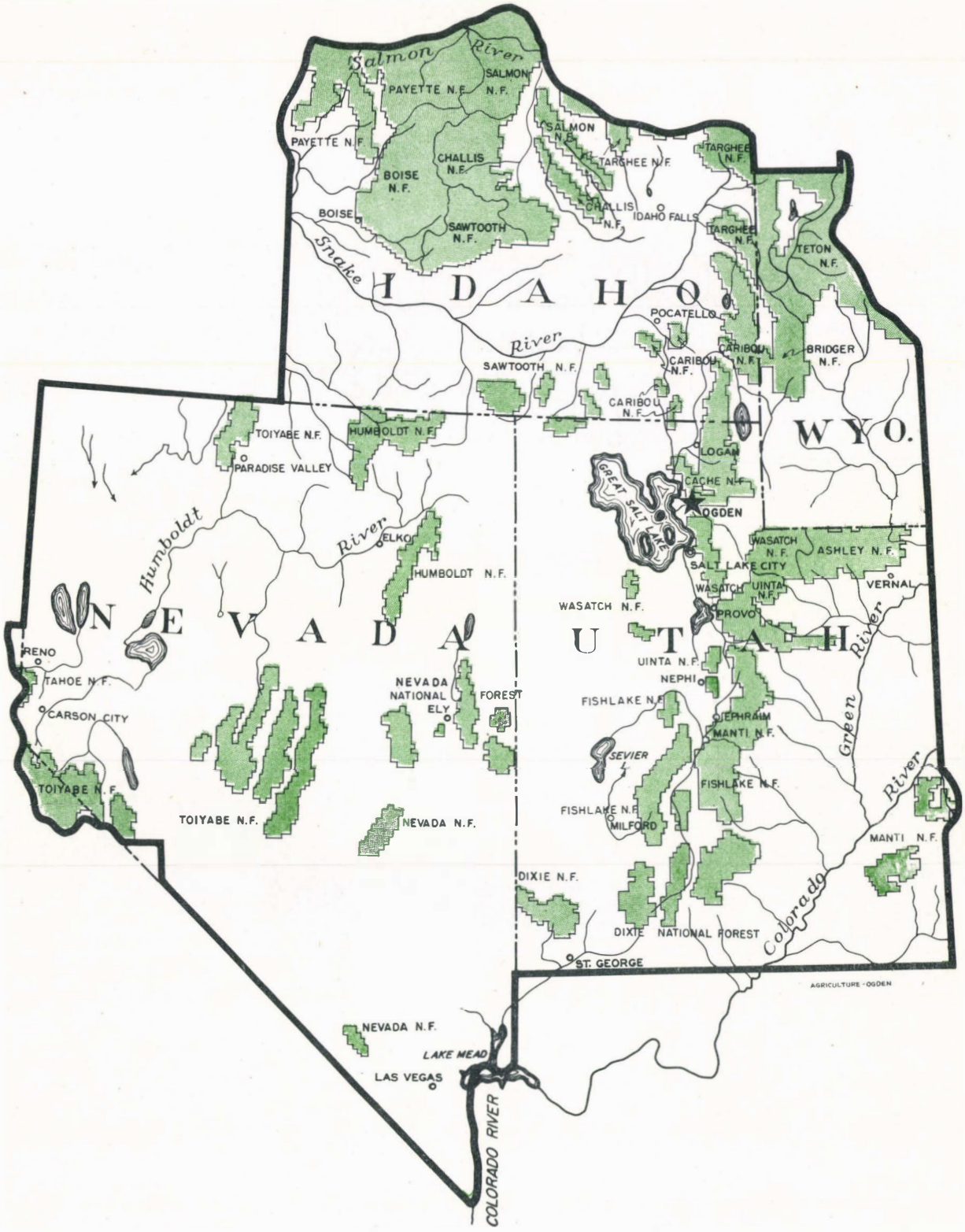

Figure 1.--National forests of the Intermountain region.

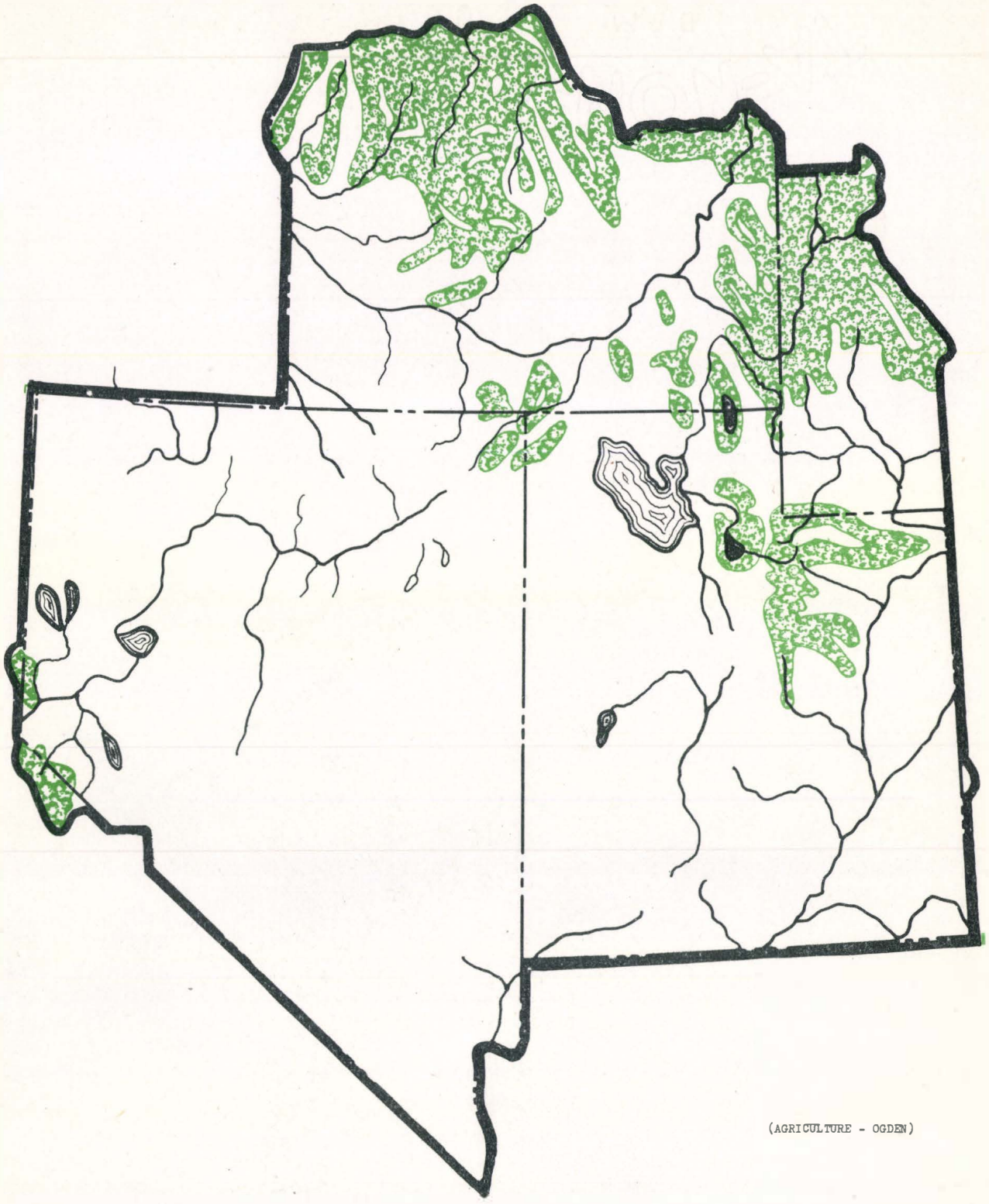

Figure 2.--Botanical range of lodgepole pine in the Intermountain region.

The growing season in typical lodgepole areas is short, probably from 50 to 65 days, suggesting limited growth possibilities. Mean monthly temperatures during the growing season are from 45° to 60° F.; minimum annual temperatures are between -20° and -30° F.

Lodgepole pine stands.--Lodgepole pine grows in both pure and mixed stands up to 350 years old. Stands may be even-aged, two-aged or uneven-aged,[4/] and in some areas all three kinds are found near one another. These variations in stand structure and composition are a result of either past cuttings, fire, insects, or disease.

In mixed stands the principal associates of lodgepole are ponderosa pine (Pinus ponderosa Laws.) and Douglas-fir (Pseudotsuga menziesii var. glauca /Beissn./ Franco) at the lower half of its elevational range, and alpine fir (Abies lasiocarpa /Hook./ Nutt.) and Engelmann spruce (Picea engelmannii Parry) at the upper limit. Lodgepole also occurs in some areas with quaking aspen (Populus tremuloides Michx.).

Lodgepole pine stands occur at elevations above sea level from 4,500 feet in Idaho to 10,500 feet in Utah but their best development is between 6,500 and 9,500 feet elevation.

Commercial stands occur on all degrees of slope and aspect but the best stands are on level to moderately sloping terrain on north, northeast, or east exposures. The physical appearance of the ground surface appears to have little bearing on the natural occurrence of lodgepole, as excellent stands are found as often on ground strewn with large boulders as on smooth terrain.

While this species appears to grow best on moist, well-drained soils it occurs on a wide variety of soil conditions in the Intermountain region. For instance, in central Idaho extensive stands occur on loose, desiccative soils of granitic origin, in southeastern Idaho on soils derived from lavas, and in western Wyoming lodgepole grows well on soils of shale and sandstone origin.

Stand volumes vary from less than 1,000 board feet per acre in the pure lodgepole type where trees are of small diameter to 20,000 board feet per acre in mixed old growth.

A brief description of the lodgepole pine stands in some specific localities within the Intermountain region follows:

In the "back country" of central Idaho a large volume of old-growth lodgepole in mixed stands was killed by the mountain pine beetle (Dendroctonus monticolae Hopk.) 20-25 years ago. Mortality of sawlog-size trees ran as high as 90 percent in some stands. Although Engelmann spruce and alpine fir predominate today in the overstory, vigorous immature and young lodgepole now occupy the openings caused by the infestation.

4/ The term "uneven-aged" used here follows its accepted definition (58), as do all other commonly used forestry terms.

In southeastern Idaho, principally on the Targhee National Forest, extensive areas of pure, even-aged pole-size lodgepole occur. There is evidence that these stands are of fire origin. Similar but less extensive stands are present elsewhere in the Intermountain region.

On the Targhee section of the high plateau which extends across the western edge of Yellowstone National Park are old-growth lodgepole stands of large-sized trees. Representative of many other cutover areas in the region a part of this tract, the Moose Creek Plateau, was partially logged 20 to 25 years ago for hewn railroad ties. Only the trees between 11 and 16 inches d.b.h. were removed because they were the minimum and maximum acceptable sizes for hewing. Many of the residual trees have since been windthrown. Dwarf mistletoe (Arceuthobium americanum Nutt.) and heart rot are prevalent in those still standing as well as in poles and saplings that have come in beneath the reserve stand. The uncut stands on this plateau appear to have less mistletoe, the trees within them being better formed and having more vigorous crowns.

In western Wyoming on the Bridger National Forest unlike southeastern Idaho, much of the lodgepole occurs patchwise. Distinct changes in stand structure and composition are apparent with breaks in topography and on opposite sides of minor drainages. South slopes in general support a sagebrush type. The north slopes of canyons through which streams flow east into the Green River are fairly well timbered. In one area on Beaver Creek where one of the more recent timber sales is located, no less than four distinctly different kinds of lodgepole stands occur within a distance of less than a mile. Pure, immature pole stands as well as old-growth pole stands are intermingled with uneven-aged stands of mixed species.

Some of the lodgepole stands at the headwaters of minor streams and on the upper slopes of the Greys River drainage are a little more continuous and uniform in nature. These are, however, predominantly mixed stands and in which all species appear to reach their best development. Mature lodgepole pine reaches a height of 80 to 90 feet and a d.b.h. of 20 to 26 inches. Fir and spruce of the same height and 30 to 36 inches d.b.h. are common. Larger trees than this can be found.

The southernmost major lodgepole area of the region is in the Uinta Mountains in northeastern Utah. This range with a length of about 100 miles and a width of 35 to 50 miles forms the largest mountain mass with an east-west axis in the United States. Lodgepole stands of varying makeup can be found at elevations up to 10,500 feet on both its north and south flanks. On some areas bordering large parklike flats are found some of the oldest and coarsest lodgepole pines in the region.

Thus considering the structural complexity of many of these lodgepole stands, their location, the growth limitations imposed by altitude, and the small sizes of trees, management of this species presents a formidable field of endeavor for the silviculturist, the logging engineer, and the forest economist.

Economic and Social Aspects

A study of the economic importance of the lodgepole forests in this region has never been made. The latest estimates of area and volume are from the 1945 reappraisal of the forest survey made in 1931. Furthermore, there are no accurate figures on the actual amount of lodgepole in all product forms removed annually from the forests, since it has been customary to include lodgepole with other species except ponderosa pine when reporting annual cut.

It would be extremenly difficult, therefore, to single out the separate contributions that lodgepole forests make to agriculture, mining, manufacture, and related components of the economy of the Intermountain region. For the most part these forests are yet undeveloped and should be viewed in the light of their potential rather than their past values.

Land area and ownership.--The total forested land area of the region is 23,922,000 acres, of which it is estimated the lodgepole pine type occupies about 4 million acres or 17.0 percent. Some 90 percent of the lodgepole stands are in Federal ownership.

Thirteen years ago it was estimated (46) that some 25 percent of the commercially important forest land in the Intermountain region was lodgepole pine. This meant that only about 1.4 million acres or slightly more than one-third of the lodgepole stands were then considered operable. The balance, about 2.6 million acres, was either inaccessible or too poorly stocked to be considered for timber exploitation under existing conditions.

But today the picture was changed. All forests supporting lodgepole have reported a steadily rising demand for more timber, and population growth and industrial expansion constantly reflect a greater need for the middle and lower grades of lumber. During the past two years two Swedish gang mills have been installed in Idaho, the first in the region. It is significant that some of the logs these mills use are from stands which were not believed suitable for sawlogs 5 years ago because they were sparsely stocked with short, small-sized trees. Lodgepole logs down to 6 inches in diameter are now being run through these mills.

Population and employment.--There were more than 1.3 million people in Region 4 according to the 1950 census, representing a 25-percent increase over the 1940 estimate (table 1). This is typical of many areas in the West and is reflected in the increasing wood requirements of the region.

The greater percentage of the entire population is engaged in occupations directly or indirectly related to agriculture and the livestock industry. Mining provides employment to a relatively small number of people although from the standpoint of capital investment and value of products it ranks high.

Table 1.--Population - Region 4[1/]

State	Year		
	1950	1940	1930
Nevada	160,083	110,247	91,058
Utah	688,862	550,310	507,847
Idaho[2/]	446,473	389,097	325,092
Wyoming[2/]	43,445	42,237	39,578
Total	1,338,863	1,091,891	963,575

1/ From 1950 United States Census of Population.
2/ For part of state in Region 4 only.

Probably not more than 10,000 people are employed in all forest industries of the region.[5/] Only a small number of inhabitants are directly dependent upon lodgepole pine for their livelihood, yet indirect benefits from these forests are enjoyed by almost the entire population and hundreds of thousands of visitors each year.

Sawtimber volumes.--Volumes of sawtimber by species on the national forests of Region 4 are shown in table 2. About 2½ billion board feet or 17.1 percent of this sawtimber is lodgepole pine. There is reason to believe that this is a conservative estimate and will be revised upward when the Forest Survey is completed.

Table 2.--Volume of sawtimber by species in Region 4 national forests 1/

State	Douglas-fir	Ponderosa pine	White fir	Engelmann spruce	Lodgepole pine	Western larch	Other	Total
	Millions of board feet							
Colorado	--	21.3	--	--	--	--	--	21.3
Idaho	2,801.0	3,359.9	406.2	563.8	451.0	40.7	--	7,622.6
Nevada	.5	44.6	25.6	3.2	--	--	10.3	84.2
Utah	376.6	1,132.5	194.1	1,062.4	896.7	--	--	3,662.3
Wyoming	519.8	--	74.1	684.1	987.8	--	--	2,265.8
Total	3,697.9	4,558.3	700.0	2,313.5	2,335.5	40.7	10.3	13,656.2
Percent	27.1	33.4	5.1	16.9	17.1	.3	.1	100.0

1/ From Revised Timber and Area Estimates--1945. Compiled by Regional Office, Region 4, Ogden, Utah.

5/ Estimate based on 1950 census. This includes woods operations and the manufacturing of furniture, lumber, and wood products.

Lodgepole pine ranks third in volume of sawtimber among all forest tree species of the region, and yet it is the only species within the region with the combined qualities of wide distribution, utility below sawlog size, and great diversification of roundwood uses. The potentialities of lodgepole pine forests for future development are thus actually greater than for areas supporting other species.

Lodgepole pine mills.--The region is characterized by small mills (table 3). Of the 392 active mills in 1949, 352 mills, or 90 percent, cut less than one million board feet of lumber. Of the active mills, 149 or 38 percent handled some lodgepole pine; 44 of these mills cut lodgepole pine exclusively. These small mills provide employment to a number of people in rural areas and are a source of low-cost products that are needed and used locally to maintain many small communities.

The total lumber production for the region in 1949 was 301.4 million board feet; 20.4 million board feet, or 6.8 percent, was lodgepole pine (table 4). Though this is a rather small portion of total regional lumber production, it should be remembered that lodgepole pine is not exclusively a lumber species and the cubic-foot content of other lodgepole products is not truly reflected in lumber statistics.

Wood products other than sawtimber.--For every man dealing with lodgepole pine of sawlog size there are at least four men concerned with other products. The cutting of mine props, fence posts, corral poles, and potato cellar stock, for example, provides labor for many people in outlying communities. The small size of lodgepole pine in relation to major timber species has always provided an open field of endeavor for the small operator with big incentive but little capital. Some operators who cannot afford large investments in labor and equipment are able, nevertheless, to work alone or with a member of the family and maintain a reasonable standard of living by cutting and selling roundwood products. Because lodgepole can be cut dry and used for such products some of these small operators actually have been salvaging part of the losses accrued from insect epidemics. On the Payette National Forest, for example, dry lodgepole pine was sold for nearly 25 years before any appreciable amount of green lodgepole was cut.

The potentialities of pulpwood production in this region are impressive. One has but to look northward to the State of Montana to appreciate the developments that are possible in the Intermountain region. Four pulpwood operations have started in Montana within the past 5 years. One operator moved to the Targhee National Forest in 1953 and shipped the first lodgepole pine pulpwood cut in the Intermountain region.

Other "products."--Intangible benefits derived from the lodgepole forests of this region are widespread yet their value is difficult to assess. For example, like other timber types within the region, lodgepole areas provide scenic attractions and recreational outlets to hundreds of thousands of people each year. Also as a

Table 3.-- Number of active sawmills and number of active sawmills cutting lodgepole pine by size class, Region 4[1/]

Class of mill (Annual cut f.b.m.)	Idaho		Utah		Nevada		Wyoming		California		Total	
	Total active	Cutting lodge-pole	Total active	Cutting lodge-pole	Total active	Cutting lodge-pole	Total active	Cutting lodge-pole	Total active	Cutting lodge-pole	Total active	Cutting lodge-pole
50,000M and over	1										1	
25,000M - 49,999M												
15,000M - 24,999M	3										3	
10,000M - 14,999M	1										1	
5,000M - 9,999M	5				1						6	
3,000M - 4,999M	6	1					1	1			7	2
1,000M - 2,999M	18	3	3	1					1		22	4
50M - 999M	91	37	121	44	1		38	30	3		254	111
1M - 49M	46	21	40	5	3		9	6			98	32
Total 1949	171	62	164	50	5	0	48	37	4	0	392	149
Increase over 1946	17		2		2		10		3		34	
Total inactive - 1949	48		39		6		14		2		109	

Total mills 1949	501
Total mills 1946	453
Increase 1946 - 1949	48

1/ Compiled from Census of Sawmills, Region 4, 1949. Regional Office, Ogden, Utah.

Table 4.--Lumber production by species, Region 4[1/]

Species	Production	
	Board feet, thousands	Percent of total
Jeffrey and ponderosa pine	164,994	54.7
Douglas-fir	86,463	28.7
Lodgepole pine	20,369	6.8
Engelmann spruce	15,660	5.2
White fir	11,553	3.8
Other softwoods	1,546	0.5
Hardwoods	786	0.3
Total	301,371	100.0

1/ From Census of Sawmills, Region 4, 1949. Regional Office, Ogden, Utah.

habitat for wildlife some of these extensive forests are perhaps without equal. Less obvious to the casual observer but of vital importance is the part these forests play in stabilizing the soils of headwater drainages and in regulating streamflow. Along with other high elevational timber types the lodgepole forests act as vast storage areas for snow. Together these watersheds are regarded as an immense seasonal gauge for downstream agricultural and industrial water use planning.

PART II

PROBLEMS OF LODGEPOLE PINE MANAGEMENT

Because there has never been any organized attempt in this region to conduct research in lodgepole pine, problems cover the entire field of forest practices. The principal problems, however, center about methods of cutting mature and overmature stands. Of next importance are the problems in making intermediate cuttings in immature and young stands.[5/] These and other specific problems are discussed in order of apparent priority, but there is, necessarily, some overlapping.

Silviculture

Methods of Cutting

Mature and overmature stands.--How should these stands be cut? Which ones should be cut first? Is a selection system consistent with the silvical requirements of this intolerant species? If so, what kind of trees should be left for the reserve stand? What about release of mature trees? Can release after cutting really be sustained or will the effect be dissipated shortly? Can the progress of mistletoe infection be reduced by cutting? Can it be eliminated from a stand within reasonable costs? If so, by what means?

Solutions to these problems are required for both virgin and cut-over, pure and mixed stands.

Some cuttings for products have changed the age and size class distributions of uneven-aged stands; other cuttings have converted many even-aged stands to 2- and 3-storied stands. Should an attempt be made to convert these stands slowly to an uneven-aged condition and manage them under a selection system, or should they be cut clean[6/] and even-aged forestry practiced? What cutting cycle and what rotation period would be most suitable in each instance?

These are difficult decisions to make in view of the present lack of basic knowledge about these stands, and the ever present economic limitations imposed by the utilization of lodgepole.

Intermediate Cutting

Immature stands.--Some of the problems that apply to old-growth lodgepole apply also to immature stands. For example, pure, even-aged old growth often has the same diameter class distribution as pure,

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5/ "Immature stands" refer to stands 40-120 years old; "young stands" refer to stands under 40 years old.

6/ The term "cut clean" or "clean cutting" implies something more than "clear cutting." It involves the cutting of all trees from a stand, not just the merchantable trees.

even-aged immature lodgepole. Some 80-year-old pole stands and 200-year-old pole stands are now being cut for the same products--corral poles, fence posts, or mine props, depending on market requirements. It is clear that these stands, though representing similar economic entities in the same location, certainly are divergent in their silvicultural requirements. Why, then, should they be treated similarly in some instances? What are their requirements?

There are many thousands of acres of immature stands. Can they be thinned at a profit? If so, will growth be substantially stimulated? Is there an age-diameter-spacing relationship; or a crown-height-spacing relationship? What growth rates are considered acceptable?

What time interval should there be between thinnings? How about windfirmness? Is it possible to develop a crown-height-diameter criterion to aid in selecting trees for cutting so as to minimize wind loss? What about site? (Site classes are not used at present.) What part can pruning play to improve quality? Is weeding in certain mixed stands necessary or even practical?

Because immature stands supply a substantial share of roundwood products used throughout the Intermountain region, an understanding of their growth requirements is basic to the development of thinning and other improvement practices, to insure a sustained flow of these products to existing markets and a final harvest product in a reasonable rotation period.

Young stands.--These stands range from the thicket type, formed through rapid and prolific establishment of seedlings following fire, to the sparsely regenerated fail areas where either intensity of burn, climate, or some biological factor or a combination of these have been unfavorable for the establishment and growth of seedlings.

Numerous silvical and economic problems are posed by these stands. For example, what are the factors that inhibit their formation in some instances and favor excessive stocking in others? Can trees of this age group locked in competition for several decades be released by thinning? What methods are best? Mechanical? Chemical? At what cost can the job be done?

Many of the problems relating to cutting in these stands are similar to those encountered in the cutting of immature stands. However, there is seldom a market for the small trees removed from young stands and therefore no immediate monetary return; the entire cost of treatment must be invested in the stand. But the questions of when and how much to invest in them can be answered only through systematized research.

Utilization

The degree and limit of utilization have a decided influence on the practice of silviculture in Intermountain lodgepole pine. Because

timber stands and markets are usually remote from one another, most operators cut only the products which they can readily sell in the markets nearest their operations. As a result, for example, on sawtimber operations a startling number of submerchantable-sized trees and logs are left in the woods. The efforts of timber sale administrators to practice heavier cutting where it appears necessary and to enforce better utilization are often thwarted by their knowledge of limited markets.

At present there is no pattern to the cutting of similar stands throughout the region. For instance, on the Ashley Forest in Utah in some uneven-aged stands it is possible to clear-cut and utilize practically all trees down to 4 inches d.b.h. (sawlogs 11 inches and above, mine props down to 7 inches, and fence posts and corral poles down to 4 inches). In similar stands on the Bridger Forest in Wyoming, however, only the trees 11 inches d.b.h. and larger are marked for cutting, as railroad ties are the sole product in demand. In Idaho on the Sawtooth Forest certain 80-year-old stands can be clean-cut and trees can be utilized to a 2-inch top, whereas on the Targhee Forest in similar stands only light thinning is possible.

But is the absence of product integration on individual sales a necessary evil? How can distant markets be made to fall within the limits of profitability?

Would the development of cheaper methods of logging small stems enhance the possibilities of better utilization? Perhaps some drastically different yet soundly conceived system of logging must be introduced. Why hasn't the Wyssen system of logging been tried? On steep terrain would not this system lend itself to more economical removal of a large quantity of small logs? With small portable mills cannot operational costs be lowered by installation of properly designed labor- and time-saving devices? Would not some operators be able to cut and haul products other than ties and sawlogs if better haul roads were constructed into sale areas so that hauling costs would be reduced? These better haul roads would ameliorate the effect of the short, 3- to 5-month operating season on annual production.

When individual products are considered, pulpwood stands out as one with a great future potential. However, there are no pulp mills in the Intermountain region. The principal obstacle in exporting pulpwood today is the high freight rate to pulp mills outside the region. Also to be considered are some of the long truck hauls, 80 to 110 miles from woods operations to the railheads.

Obvious silvicultural benefits result when lodgepole pine can be cut for pulpwood. For example, heavily mistletoed stems of little or no use for sawtimber or poles can be cut to a 6-inch diameter and a 4-inch top resulting in excellent utilization. Since this in turn means heavier cutting than on most present operations more favorable conditions for restocking of lodgepole are created.

If benefits from cutting pulpwood are to be realized based on a market outside the region, therefore, the problems of effecting lower freight rates and reducing handling and hauling costs must be faced.

There are still other utilization problems that merit consideration. For example, lodgepole pine takes preservative treatment readily and is considered excellent for fence posts, highway posts, and similar products. With dwindling supplies of good quality cedar and juniper posts and poles, what are the post-and pole-treating opportunities for lodgepole pine in this region? What are the regional requirements for treated products? Can the region support any new wood-preserving plants? Are consumers fully aware of the superiority of treated lodgepole pine posts over untreated, or is more extension work needed to convince them? With the wide distribution of lodgepole and the distance of markets from some major sources of supply, it is impossible for small, individual operators to realize all the outlets for their products. Would more lodgepole be taken out of the woods if major concentration yards were established to serve as a link between the small producer and the user?

Obviously, utilization problems in lodgepole pine management resolve into a technical, economic, and educational complex.

Forest Survey

For intelligent management of the timber resources in the Intermountain region dependable estimates of forest area, timber volume, growth, and yield are needed. Since initial survey data are lacking for the lodgepole pine type, resource managers are at an obvious disadvantage when regional planning activities must be carried out. The species, kind, location, and ownership of stands that occur within the lodgepole type must be known, together with their volume and growth and depletion rates.

Other pertinent information essential for a sound appraisal of the forest situation is also lacking. For example, how much logging waste is created by different kinds of operations? In what form does this waste remain? Cull logs of sawlog size? Tops? Small trees knocked down in logging? Can this so-called logging waste be economically removed and sold? If so, what are the prospective uses for such material in specific areas within the region?

Silvics

Management of lodgepole pine, like the management of any forest type, depends upon basic silvical facts.

Early cutting did not consider several major silvical requirements of lodgepole pine and associated species. For example, commercial cuttings in many mixed stands have resulted in a distinct trend toward conversion to more tolerant species such as alpine fir and

Douglas-fir. Selection cutting in stands infested with dwarf mistletoe has been followed by intensification of the infection in the reserve stand and reinfection of the new stand where restocking has taken place.

Past thinnings in dense pole stands have been too light, as growth response from them has been negligible.

To avoid these results in future cuttings, considerable research is required. Can type conversion be prevented within reasonable costs? Should it be prevented? Can a method of measuring the degree of mistletoe infection on individual trees or within an entire stand be formulated? What specific affect does mistletoe have on the physical characteristics of a tree? Does it affect height, diameter, or volume growth? If so, are the effects measurable? If these effects are altered by controlling mistletoe can their importance be appraised in terms of silvicultural or economic benefits?

What factors govern growth response to release in individual trees? Crown length, width, or vigor? How is diameter growth related to height growth? What part does root competition play in growth stagnation?

Likewise, studies are needed of physiological variables (light, temperature, humidity, and soil) and their affects on the growth and development of trees and stands. For example, which of these factors has the maximum affect on cone opening in logging slash or on viability of seed? What are optimum conditions for cone opening in various densities of slash? Will seeds remain viable in closed cones buried in the duff? If so, for how long a period of time?

The role of fire as a silvicultural tool in lodgepole management must be clarified. Is burning necessary to open cones in dense slash? If so, when should burning be carried out? Spring? Fall? Winter? What density and arrangement and what type of burn of slash are required for satisfactory results? A rapid, light burn? A slow, hot burn? How can rate of burn be controlled?

Recently a clue to an association between bark-eating rodents and stem rusts (Cronartium spp.) has been revealed, as well as an association between stem cankers and pitch moth damage. But what is the nature of these relationships, are they important, and will they affect silvicultural practices?

Mensuration

Volume tables.--No mensurational studies have been made in Intermountain lodgepole pine. The volume table in current use throughout most of the region was constructed from tree measurements on the Uinta National Forest in Utah. Is the regionwide use of this volume table justified or should volume tables be constructed for individual forests or ranger districts? Basic data for this table were derived from trees

9 to 18 inches d.b.h., but the table has been extended without additional data to 29 inches d.b.h. Use of the extrapolated table values to determine volumes of large trees probably results in great inaccuracies.

Several important factors in volume table construction must be investigated before adequate tables can be prepared. For example, to what extent does stem taper and form vary from stand to stand? What is the effect of site and stand density on these factors? Does cull vary from stand to stand and from one part of the region to another and, if so, to what degree?

Another problem is the adaptability of lodgepole pine volume tables from other regions for use here.

An unusual situation on the Wasatch Forest requires that trees be sold by weight instead of volume. The product, converter poles, is purchased and used in copper smelting in unpeeled tree lengths. Since there is no weight-volume table, scalers must rely on meager data from occasional truck weighings by the purchaser at the smelter, an arrangement which obviously does not assure accuracy in accounting for wood sold. Before this necessary table can be constructed, however, certain questions must be answered. For example, what is the relationship between weight and volume in green lodgepole pine on this forest? Do trees of equal diameter vary in weight from stand to stand? From wet sites to dry sites? And if so, how much do they vary?

Growth and yield.--How fast are lodgepole stands of different ages growing? How does stand density affect growth? Is growth affected more by age than by crown length and condition? What growth rates can be considered satisfactory in different classes of stands? Is d.b.h. or height a reliable indicator of site? Do normal-yield-table-methods of growth prediction apply in lodgepole pine? If not, what methods are best for determining yield? These are some of the principal questions for which there are at present no answers.

Tree marking.--There are several problems in tree marking which are more of the administrative than the research type but which nevertheless deserve mention. Not all lodgepole sales in this region employ sampling methods in marking timber and this is especially true of small product sales. Considerable time is spent on these sales by forest officers when individual trees must be marked. In some instances the total value of the product sold is but a small amount when compared to the cost of sale administration. Can marking time be reduced or perhaps eliminated without sacrifice in accounting accurately for products sold? What sampling methods can be used in marking lodgepole pine?

Artificial Regeneration

Restocking through artificial means is necessary in burns and in cutover areas that have not reseeded naturally to lodgepole pine. From what localities should seed be collected for use in different parts of

the region? Is seed spotting a practical method of restocking cutover areas or should they be planted? When should seeding or planting be done? Spring? Fall? What age and grade of stock is best for planting under Intermountain conditions of soil, precipitation, altitude, and topography? What type of protection from rodents, livestock, or other agents is required for seed spots or planted stock?

PART III

PROBLEM EVALUATION

Silviculture

Methods of Cutting

Methods of cutting have been called "the heart and soul of silviculture" (2). Visual emphasis of situations where the heart has failed but the soul remains is given by the lodgepole stands in figures 3 and 4. Both of these stands were cut for specific products only--railroad ties in figure 3 and corral poles and posts in figure 4. It should be appreciated that at the time these stands were cut there were no other markets nearby. Clearly demonstrated is the positive affect that utilization has on cutting when follow-up measures aimed at putting the stand in a productive condition are not employed. There is certainly no way to convert these areas into a productive condition now without complete removal of all trees as an initial step.

Illustrative of cases where markets permitted heavy cutting, are the lodgepole stands in figures 5 and 6. Obviously, these cuttings portray the opposite extremes of utilization and expected silvicultural results than the cuttings illustrated in figures 3 and 4. The good utilization demonstrated in figures 5 and 6 cannot be achieved in all lodgepole stands throughout the Intermountain region.

What kinds of mature and overmature stands are there?--Observations and age determinations made by the writer on twelve national forests in the Intermountain region and in Montana and Colorado have led to the conclusion that lodgepole pine stands fall logically into a recognizable pattern. With a little study and practice this pattern is easily learned and interpreted.

A preliminary classification of lodgepole pine stands in the Intermountain region is presented in figure 7. The principal features of this classification are: (1) It includes both virgin and cutover stands. (2) It shows the classes of stands--their age, structure, and composition in general terms. (3) It indicates the principal factors responsible for their formation.

As an initial step toward gauging the scope of methods-of-cutting problems and also as a preliminary guide in management, brief descriptions of each of the mature and overmature stands in the classification are outlined below. Age determinations by the usual field methods are, of course, necessary for accurate delineation of age classes. Immature and young stands are discussed under the subject, "Intermediate Cuttings."

1. Pure, even-aged, mature or overmature (fig. 8).

   Generally single-storied.

   a. Uniform appearance in diameter and crown length.

   b. Live crown length generally short to medium (30-60 percent of tree height); boles may be clear for 10-40 percent of tree height.

   c. Limbs fine in appearance except in very old stands.

   d. Few or no coarse-limbed wolf trees throughout the stand.

   e. Uniform stocking except in very old stands.

2. Pure, two-aged, mature or overmature.

   Generally two-storied but may be single-storied.

   a. Two-storied--the younger-aged trees occur exclusively as understory, may be either immature or young, and are of smaller diameter than the old growth. The overstory resembles an even-aged stand.

   b. Single-storied--the younger-aged trees are immature, have finer limbs than the old growth, and may or may not be of diameter equal to the old growth. Otherwise resembles an even-aged stand.

3. Pure, three-aged, mature or overmature (fig. 9).

   Generally three-storied but may be two-storied.

   a. Three-storied--overstory is mature or overmature; middle-story is immature; understory is young.

   b. Two-storied--overstory is two-aged, the younger trees immature; understory is young.

4. Pure, uneven-aged, mature or overmature (fig. 10).

   Generally multi-storied but may be single-storied.

   a. Greater range in diameter classes than in even-aged stands.

   b. Original seed trees are present and are large-sized and coarse-limbed.

   c. Fill-in trees are better-formed and finer-limbed than original seed trees.

Figure 3.--Pure, uneven-aged, overmature lodgepole pine culled for railroad ties. Windfall, heart rot, and mistletoe are abundant in this stand. Note reproduction that has become established where cutting was heavy. Targhee National Forest, Idaho.

Figure 4.--Pure, even-aged, overmature lodgepole pine culled several times within the past 20 years. Numerous trees have been windthrown. Mistletoe present in the virgin stand has increased in vigor through gradual opening up of the stand. The parasite has spread to residual trees and is annually infecting young reproduction. Payette National Forest, Idaho.

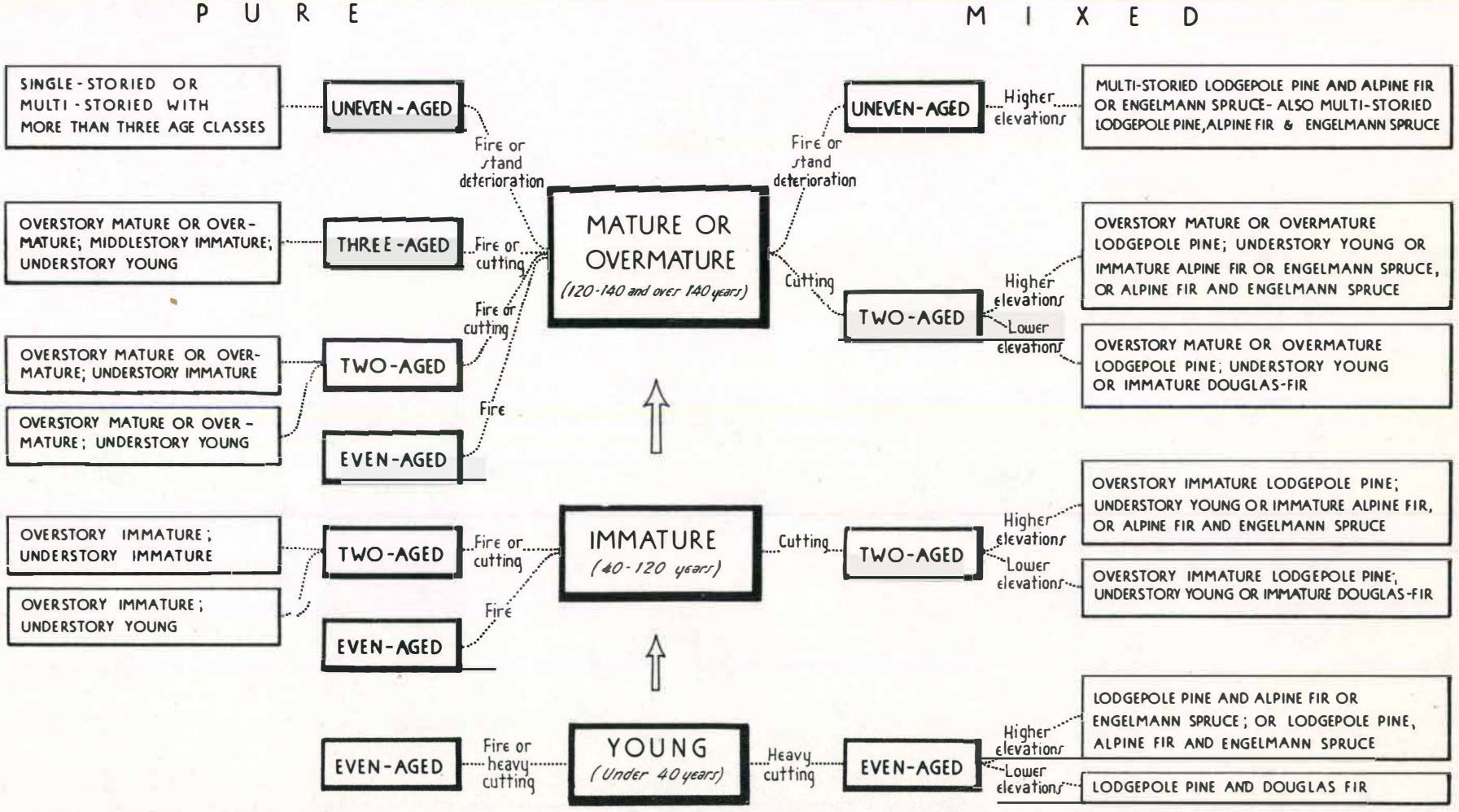
Figure 5.--Pure, two-aged, overmature lodgepole pine clean-cut for pulpwood. Gallatin National Forest, Montana.

Figure 6.--Pure, uneven-aged, overmature lodgepole pine clear-cut for mine timbers and ties. Wasatch National Forest, Utah.

Figure 7

LODGEPOLE PINE STAND CLASSIFICATION

(PRELIMINARY)


P U R E
M I X E D
SINGLE-STORIED OR MULTI-STORIED WITH MORE THAN THREE AGE CLASSES
UNEVEN-AGED
OVERSTORY MATURE OR OVER-MATURE; MIDDLESTORY IMMATURE; UNDERSTORY YOUNG
THREE-AGED
OVERSTORY MATURE OR OVER-MATURE; UNDERSTORY IMMATURE
TWO-AGED
OVERSTORY MATURE OR OVER-MATURE; UNDERSTORY YOUNG
EVEN-AGED
Fire or stand deterioration
Fire or cutting
Fire or cutting
Fire
MATURE OR OVERMATURE
(120-140 and over 140 years)
Fire or stand deterioration
Cutting
UNEVEN-AGED
Higher elevations
MULTI-STORIED LODGEPOLE PINE AND ALPINE FIR OR ENGELMANN SPRUCE- ALSO MULTI-STORIED LODGEPOLE PINE, ALPINE FIR & ENGELMANN SPRUCE
TWO-AGED
Higher elevations
OVERSTORY MATURE OR OVERMATURE LODGEPOLE PINE; UNDERSTORY YOUNG OR IMMATURE ALPINE FIR OR ENGELMANN SPRUCE, OR ALPINE FIR AND ENGELMANN SPRUCE
Lower elevations
OVERSTORY MATURE OR OVERMATURE LODGEPOLE PINE; UNDERSTORY YOUNG OR IMMATURE DOUGLAS-FIR
OVERSTORY IMMATURE; UNDERSTORY IMMATURE
OVERSTORY IMMATURE; UNDERSTORY YOUNG
TWO-AGED
EVEN-AGED
Fire or cutting
Fire
IMMATURE
(40-120 years)
Cutting
TWO-AGED
Higher elevations
OVERSTORY IMMATURE LODGEPOLE PINE; UNDERSTORY YOUNG OR IMMATURE ALPINE FIR, OR ALPINE FIR AND ENGELMANN SPRUCE
Lower elevations
OVERSTORY IMMATURE LODGEPOLE PINE; UNDERSTORY YOUNG OR IMMATURE DOUGLAS-FIR
EVEN-AGED
Fire or heavy cutting
YOUNG
(Under 40 years)
Heavy cutting
EVEN-AGED
Higher elevations
LODGEPOLE PINE AND ALPINE FIR OR ENGELMANN SPRUCE; OR LODGEPOLE PINE, ALPINE FIR AND ENGELMANN SPRUCE
Lower elevations
LODGEPOLE PINE AND DOUGLAS FIR

Prepared by D. Tackle.
P.N.W.

Figure 8.--Pure, even-aged, overmature lodgepole pine. Gallatin National Forest, Montana.

Figure 9.--Pure, three-aged, overmature lodgepole pine. A two-storied stand. The understory is in the young age class; the overstory is a mixture of immature and overmature trees. Center tree and tree on extreme right are overmature; the other three finer-limbed trees are immature. Sawtooth National Forest, Idaho.

Figure 10.--Pure, uneven-aged, overmature lodgepole pine. Note dead, leaning "mother" tree with rapid taper. Other trees like this one, some living, are scattered through the stand. Bridger National Forest, Wyoming.

d. If original stand is quite dense there is little difference between old and new stand.

e. If uneven-aged condition is caused by gradual deterioration of an even-aged stand, nearly all the healthy, fast-growing trees are below sawlog size.

f. Occasionally stocking may be irregular.

5. Mixed, uneven-aged, mature or overmature (fig. 11).

a. Less than 80 percent lodgepole pine in the overstory, either by number of stems or volume.

b. Otherwise has same basic characteristics indicated for pure, uneven-aged, stands.

6. Mixed, two-aged, mature or overmature.

a. Two storied.

b. Overstory is pure mature or overmature lodgepole pine; understory is immature or young Douglas-fir, alpine fir, or a mixture of alpine fir and Engelmann spruce.

What is known about cutting mature and overmature stands elsewhere?--In Colorado and Wyoming, Taylor (60, 61) developed a tree classification for marking lodgepole pine stands for selection cutting based on the crown characteristics of area, length, and vigor. In testing this classification he showed that response to release is principally a function of the crown vigor classes and amount of release given by cutting, and that it is correlated with diameter only up to 12 inches d.b.h. Increased growth due to release was found to decline in from 14 to 18 years after cutting and by 30 years showed a very marked reduction. Under no condition was age found to be correlated with diameter in lodgepole pine.

The writer has found stands in which lodgepole reproduction has become established under a fairly dense overstory, somewhat like under a shelterwood cutting. Similar stands have been found by other workers,[7/] (43). Reproduction in these stands may be due to some particularly favorable soil condition or to the existence of a shade-tolerant lodgepole ecotype. No research on these hypotheses, however, is found in the literature.

Clear-cutting was one of the earliest methods used in harvesting lodgepole pine (31, 47). It was first practiced on areas in Montana and Colorado where markets for hewn railroad ties, telephone poles, mine props, and mine ties were reasonably close to the timber stands. The method was prompted, then, not so much on silvicultural grounds as through necessity during early settlement of the West.

7/ Personal communication - Bert Lexen, U. S. Forest Service, Washington, D. C.

Early proponents of clear-cutting (10, 15, 47) recognized, however, that this method satisfied the silvical requirements of lodgepole pine. Recently (2, 43, 44) the results of these early workers have been substantiated and extended to fit present day ecological knowledge of the species. The facts which justify clear-cutting mature and overmature stands and which appear to make partial cutting of any kind impractical for wide application are summarized as follows:

First, because lodgepole is a shade-intolerant species, it reproduces most satisfactorily when the stand is opened up greatly, as by heavy cutting. Second, although not always visibly detectable, mistletoe is present in a majority of old-growth lodgepole stands. Considering the ecology of mistletoe, any form of partial cutting in stands where this parasite is well established tends to favor new infection on healthy reproduction.

Third, wind loss, while variable is always a serious threat in the lodgepole type. The seemingly favorable growth advantage in stands given a selection cut can be quickly destroyed by a severe wind, and, therefore, until more is known about wind affects in relation to crown characteristics, topography, and soil, partial cutting of any kind in old-growth lodgepole pine leaves much to be desired.

Finally, considering the vigor, health, and tree sizes present in old-growth lodgepole stands, partial cuts are apt to leave many cull trees and small trees that are nevertheless old and will not respond to release, thus making future cuts of little or no value.

Much thought has been given to slash disposal methods from the standpoints of both fire protection and regeneration. Because of the heavier quantity of slash resulting from clear-cutting as compared to lighter cuts the fire hazard is greater, thus necessitating more slash disposal. The method of slash disposal is vitally important, since in clear-cutting regeneration is obtained principally from seed in the slash.

Broadcast burning has been attempted on both clear-cut and partially cut areas (12, 48, 62). This method results in overly dense reproduction where a light, uniform burn is achieved, poorly distributed, sparse reproduction where coverage of the area by fire is incomplete, or no reproduction where a hot fire consumes the seed. On partially cut areas there is also danger of damage to the residual trees by fire. Because of variations in fuel, humidity, slope, and other physical factors it is extremely difficult to obtain a desirable degree of broadcast burn and there are few instances where the right degree has been achieved.

Where piling and burning is practiced residual trees suffer less damage than with broadcast burning (48), yet an appreciable amount of damage through scorching of tree trunks and killing of roots under the slash piles occurs even when slash piles are properly located. The seed stored in cones in the piled slash is usually consumed by the fire. While the cost of this method is high it is probably the best one to use along rights-of-way and in high-use recreation areas for the purpose of fire hazard reduction. On other areas its use is questionable.

Figure 11.--Mixed, uneven-aged, overmature lodgepole pine. Lodgepole pine, alpine fir, and Engelmann spruce are the associated species. Cache National Forest, Idaho.

Another method, windrowing of slash, was practiced extensively on private lands in Montana before the turn of the century (31). This method was recently employed on some of the pulpwood cuttings in Montana and on similar operations in southeast Idaho. It has been estimated (49) that windrowed slash takes some 40 years to decay if not burned, thus maintaining a high fire hazard. When burning of windrows is carried out the fire burns so hot that all seed in, as well as out of, the cones is consumed. This can occur even when burning is done with snow on top of the slash. If windrows are not burned, however, little if any reproduction can be expected to come up through them except along their edges, because of the heavy density of the slash.

Where windrowing of slash is a necessity because of the nature of the logging operation, as in the pulpwood cutting depicted in figure 5, something may have to be done with the slash after it is windrowed if the area is to be regenerated to a desirable density. It may be well to consider returning a portion of the green slash to the cleared areas after the pulpwood is removed to assure a reasonably well distributed seed source for the clear-cut area.

Among all slash disposal methods suggested, lopping and scattering or dozer piling and burning only that portion of the slash necessary to meet fire protection standards, offer the best chances of success in restocking clear-cut areas to a desirable density (10, 12, 13, 43). No single method has been successfully carried out on all types of selectively cut areas. Each presents an individual problem depending upon the amount, kind, and distribution of the reserve stand.

To what extent can existing knowledge be applied in the Intermountain region?--On the basis of the foregoing evidence it is believed that some form of clean-cutting would be best for all pure, mature and overmature stands in the region. The adoption of even-aged management need not, however, preclude the use of some form of a preparatory cutting in certain stands. For example, in a pure, two-aged, mature stand where the younger age class consists of vigorous, immature trees, the first cut might well remove the older age class. If stand density can be controlled to avoid regeneration from becoming established the second and final cut some years hence would be a clean-cutting to obtain regneration.

In stands where more than a single cut does not seem feasible on economic grounds, stand improvement funds[8/] will have to cover the cost of removing all unmerchantable trees to effect clean-cutting in a single cut.

Clean-cutting in pure, mature and overmature stands at present appears to be limited to the Ashley and Wasatch Forests in Utah because of the heavy demand for mine timbers in that locality, and to a part of the Targhee Forest in Idaho where pulpwood is being cut.

8/ Money deposited by a timber contractor to the account of the Forest Service to finance post-logging stand improvement work.

Since little is known about the management of mixed stands in which lodgepole pine is a component, no specific guides can be laid down. Nevertheless, certain facts and experience elsewhere should be carefully considered when such stands are to be cut.

It is believed that lodgepole silviculture has not yet reached the stage where we are prepared economically to maintain this species on areas where its existence as a subclimax type is most strongly asserted. No major attempts, therefore, should be made at wholesale treatment of mixed stands to favor lodgepole pine but the best use that can be made of each species without affecting the stand adversely should be practiced. There are two important factors that justify this viewpoint.

First, the silvicultural requirements of lodgepole pine are decidedly different to those of other species with which it most frequently associates in the Intermountain region. Balking nature is costly, and can only be done safely where ample evidence has proved that such a course is an ecologically sound plan.

Second, recent experience in other regions with some of the once-inferior species reveals the costly errors that may result from failure to consider their future potentialities. For example, western hemlock (Tsuga heterophylla /Raf./ Sarg.) and white fir (Abies concolor /Gord. & Glend./ Lindl.) were once earmarked in this category, but changing economic conditions have shifted them to the more respectable class of commercial species. Is it too fanciful to assume that 25 or 50 years hence some of the Intermountain species now seldom accepted will be in demand?

Some new opinions on slash disposal are also warranted by recent observations. The firmly entrenched idea that burning and lodgepole regeneration always go hand in hand is the result of failure to recognize that fire in slash and fire in an uncut green stand are two different phenomena. This idea is untenable by virtue of the different position of the cones and the divergent physical arrangement of fuels in each circumstance. Furthermore, fire in slash is complicated still more by the factors of time of year when the timber was cut and elapsed time and seasons of the year between felling and burning. These factors have been too often overlooked.

The writer has found numerous examples where identical piling and burning practices have been carried out at different seasons of the year and for different periods of time following felling. The basic conclusions to be drawn from these observations are: (1) Burning is not essential to obtain adequate restocking. (2) If necessary to pile and burn, sufficient time must elapse between felling and piling to allow cones to open. (3) Use of a toothed dozer blade will help shake the seed from cones and eliminate unecessarily deep soil disturbance. (4) Whenever burning is practiced the area burned should be kept to a minimum. (5) Cone position in the slash with respect to height above ground level, orientation for receiving solar heat, and other conditions affecting exposure are important factors in cone opening and should receive particular attention in future research.

Intermediate Cuttings

What kind of immature and young stands are there?--A brief description of the immature and young stands included in figure 7 follows:

1. Pure, even-aged, immature (fig. 12).

   Same description as for even-aged, mature or overmature stands (page 20) except the younger immature stands are more densely stocked and less naturally pruned.

2. Pure, two-aged, immature.

   a. Either single-storied or two-storied.

   b. If single-storied, results of fire (scars or charcoal) often apparent on some of the older trees, or if caused by cutting, stumps present. Lower age class may be immature or young.

   c. Two-storied stands are self-apparent. Generally understory is in young age class.

3. Mixed, two-aged, immature (fig. 13).

   a. Overstory immature lodgepole pine; understory young or immature alpine fir or mixture of alpine fir and Engelmann spruce.

   b. At lower elevations the understory may be young or immature Douglas-fir.

4. Pure, even-aged, young (fig. 14).

   a. Generally, though not always, extremely dense.

   b. Trees of small diameter and height, with long crowns, pointed tops, and little or no natural pruning.

   c. Remnants of prior stand present in form of dense down timber, burned snags or scattered large trees, or stumps in case of cutover areas.

5. Mixed, even-aged, young.

   a. At higher elevations--lodgepole pine and alpine fir, or lodgepole pine, alpine fir, and Engelmann spruce.

   b. At lower elevations--lodgepole pine and Douglas-fir.

   c. Usually not uniformly stocked since stand condition is result of heavy cutting of a mixed, two-aged stand.

What is known about cutting immature and young stands elsewhere?--Little attention has been given to the management of immature and young stands since the major problems have been centered around old-growth timber. Conclusions from the few studies and guides concerning immature stands are as follows:

1. Good response to release can be obtained only by heavy thinning (1, 50, 55).

2. Thinning intensity may have to be adjusted to minimize wind losses at the expense of diameter growth in large pole stands (50).

3. Thinning to reduce basal area of 80-year-old stands to not less than 80 square feet per acre, and 100-year-old stands to not less than 105 square feet is recommended (43).

4. If enough trees of good form and vigor can be left to mature at age 120 to 140 years, improvement cutting should include particularly removal of cull trees and trees infected with mistletoe and Cronartium cankers (43, 47).

5. No partial cutting should be done in stands severely infected with mistletoe (44).

6. Where a thrifty stand is growing on a good site with a high wind loss potential, strip thinning may be an effective way of resolving the release-windfall complex (17).

7. Clear-cutting in strips in immature stands on poor sites can result in adequate restocking and minimum blow-down by adjustment of cut and leave strip-width (17).

Research in young stands is also limited. Reports on thinning operations in young stands by the Civilian Conservation Corps (39, 40, 42, 73) have not been followed by analysis and publication of growth data. Field inspections by the writer of many stands in which such work was performed, however, reveal the same basic principle as shown by similar work in immature stands; that is, only a heavy thinning gives assurance of subsequent increased growth. Blow-down and snow-throw in young stands are matters of small concern.

Where chemical and mechanical weeding has been attempted (16, 18) little success was achieved in trying to kill or completely eradicate the desired number of trees; therefore, neither method can be recommended without further experimentation.

From the watershed management standpoint, thinning in young lodgepole pine stands is favorable because net precipitation has been shown to increase water available for streamflow without increasing soil moisture losses or accelerating erosion when 30- to 35-year-old stands were given medium and heavy thinnings (28).

Figure 12.--Pure, even-aged, immature lodgepole pine. Challis National Forest, Idaho.

Figure 13.--Mixed, two-aged, immature lodgepole pine. Overstory is pure, immature lodgepole pine; understory is young Douglas-fir. Payette National Forest, Idaho.

Figure 14.--Pure, even-aged, young lodgepole pine. Targhee National Forest, Idaho.

To what extent can existing knowledge be applied in the Intermountain region?--Thinnings for growth along the lines suggested in item 3 can be applied on the Targhee and Sawtooth Forests and on parts of the Challis and Payette Forests. Strip clear-cutting on part of the Sawtooth Forest is possible because of a heavy demand for pole products in the nearby agricultural area. Improvement cuttings along the lines suggested in items 3 and 4 are applicable where stand conditions permit and when roundwood sales are being made. Some of these suggestions are by no means new for they have already been applied on several forests in the region.

In healthy young stands heavy thinnings may also be carried out where small products can be sold. Concentrating numerous sales on better sites will accomplish more silviculturally than scattering sales over a wider area without regard to site quality.

Utilization

An important first step toward improving wood utilization in the Intermountain region would be the employment of a full-time worker in this field at the Intermountain Forest and Range Experiment Station to insure an efficient approach to solutions on individual problems. Studies and personal contacts by such an individual would also greatly augment the extension services of state educational institutions in the region.

An analysis of wood utilization in the Intermountain region (20) has been made. The following list of recommendations from this report and from conclusions reached through recent observations in the lodgepole pine type will serve as a guide in future utilization studies.

1. Continued study on the most desirable locations for timber access roads and more access road construction as plans are completed and funds are available.

2. Better advice and greater dissemination of literature on improved logging equipment and techniques to small operators.

3. A survey of the feasibility of winter logging in the lodgepole pine type, or at least winter hauling where good roads can be built.

4. Increased advice and written information on better milling equipment and practices for small mill operators.

5. Analysis of local markets for native lumber and roundwood products including a review of interspecies competition.

6. Breaking down buyer resistance to use of lodgepole pine, alpine fir, and Engelmann spruce where these species are well suited but where habit and tradition govern the use of more valuable and higher-priced species.

7. A regional survey of wood imports and exports considering species, volume, and product class.

8. Cost studies on logging, milling, and transportation.

Mensuration

The most urgently needed kind of mensurational study is a survey of lodgepole pine stands to determine their structure and composition. A substantial amount of worthwhile basic mensurational data could be gathered through regionwide sampling of lodgepole stands as set forth in the stand classification discussed under "Methods of Cutting." Using this preliminary classification of stands as a guide in such a survey, there would be derived stand and stock tables as well as preliminary growth measurements for each stand class. An estimate of growth rates coupled with knowledge of utilization limitations for each locality would lead to a better evaluation of applicable stand treatments and a sounder appraisal of management objectives.

There are several volume tables for lodgepole pine, some of which could find use in this region. A cubic-foot volume table made by Hornibrook (36) should be checked for applicability on the Wasatch Forest. Factors for converting cubic-foot volume of the entire stem to merchantable volume are given with this table and it may, therefore, aid in developing a weight-volume table for use in selling converter poles.

A board-foot volume table made by Quintus (56) from trees in Oregon is based on a greater range in heights and diameters than the present Uinta Forest table in use here. This should be checked for applicability, revision, or replacement in some of our lodgepole forests. Because of the variation in stand makeup it is possible and should be appreciated that separate volume tables may be necessary for individual forests or even ranger districts.

Hornibrook (37) described the important defect indicators for lodgepole pine, Engelmann spruce, and alpine fir in the central Rocky Mountain region. This information should be placed before persons responsible for marking or measuring timber on each ranger district to test its adaptability and usefulness.

Before any work on growth and yield is started the summary report (35) of yield studies in selectively cut lodgepole pine in Colorado and Wyoming should be consulted. No intensive growth or yield studies should be initiated before the different classes of stands in the region have been more precisely delineated.

The present Region 4 lodgepole site table based on range in total height by d.b.h. is unsatisfactory. The true effect of site on growth and stocking is not understood. It will be necessary, therefore, to develop some new or different methods of constructing site and yield

tables. At present there are no indications of how this task should be approached because conventional methods of preparing normal yield tables do not appear suitable for this species.

Silvics

Basic silvical knowledge of lodgepole pine is fairly complete. The distribution of the species is known (59), as well as its relative physiological requirements (6,7, 26, 29), and especially its intolerance to shade (4, 8, 11, 30). A good deal is also known about the ecology of the type in this country (15, 45, 47, 51, 52), and in Canada (3, 14).

Little is known of the regional and local peculiarities (ecotypic and genotypic variation) of the species, however, and these aspects should be studied and analyzed in the light of their possible affects on management. This can be done either by making specific comparisons of climate, soil, growth, yield, and other factors or by repeat experiments to substantiate results from elsewhere for application in this region.

Numerous studies on the production, extraction, storage, dissemination, and germination of lodgepole pine seed have been carried out (5, 9, 38, 63, 66). In general, results of these experiments and basic techniques developed can be used with little or no modification here.

Additional field experimentation is needed, however, to obtain a better understanding of the relationship between slash, fire, cone opening, and seed viability. For example, cases have been found where cones in slash were not open 6 years after logging. There is some evidence that cone position in the slash and density of slash may have an important bearing on cone opening. This is important because under favorable circumstances prompt regeneration of lodgepole pine can be secured from this seed source.

The study of soil relations has received little attention. Some work in both natural and cutover stands has been reported (7, 21, 64, 65, 72) but there are conflicting results, especially the effects of fire and cutting on soils in the lodgepole type and the influence of these effects on germination and the establishment of seedlings. This is one subject which will eventually have to be considered area by area, as silvicultural efforts are intensified. A good starting point would be an intensive review of existing geological survey data and a classification of soils on a functional basis.

According to a recent summary (53) forest insect conditions in the Intermountain lodgepole type are endemic. Principal investigative effort is directed toward the detection and measurement of insect activity so that proper control measures can be applied before infestations reach epidemic proportions. Forest insect research from other lodgepole areas (22, 23, 24, 32, 34, 54) has indicated that susceptibility of stands to attack by the mountain pine beetle and possibly

other insects may be influenced by stand composition, age, diameter class distribution, available moisture, and site quality. These are some of the leads which could be followed if it were possible to undertake studies on insect relations in lodgepole stands in this region. At present a limited staff at the forest experiment station and urgent problems in the ponderosa pine type prevent the undertaking of such studies. The aid of at least another entomologist trained in forest insect ecology would be necessary to initiate work of this kind.

Disease relations have also received slight attention. The life history of dwarf mistletoe is known (69, 70, 71) yet methods for controlling this parasite suitable for widepsread application have yet to be formulated.

Field tests on the Targhee Forest to discover chemicals which will kill mistletoe have not progressed far enough to yield conclusive results. A recent report (27) on an anthracnose (Septogloeum gillii) of dwarf mistletoe on lodgepole pine in Montana has some interest from the standpoint of biological control, but it is too early to evaluate the possibilities of employing this agent for control purposes.

While it is possible that some means of chemical or biological control of mistletoe will be found, it is believed that silvicultural control will eventually prove most satisfactory and probably cheaper. Girdling, poisoning, or felling of infected trees, regardless of size, should become an established policy in lodgepole management. If stand improvement funds are insufficient to cover the cost of these post-logging treatments, some alternative plan must be found.

Forest Survey

Lodgepole pine lumber production has been rising steadily for the past 20 years (fig. 15). It is reasonable to assume that production will continue to remain at least at the same level and perhaps will move still higher, creating increased need for reliable timber resource estimates on which to base management plans.

During the past 2 years forest inventory work has been carried on in southwestern Idaho principally in the ponderosa pine type. Some initial survey work has been done in lodgepole on portions of the Targhee and Caribou Forests in Madison, Teton, and Bonneville Counties in Idaho. This area constitutes only a very small part of the entire lodgepole type within the region, however, and data from this work are not yet available.

Artificial Regeneration

No large-scale seeding or planting of lodgepole pine is anticipated in this region. Unlike ponderosa pine, the lodgepole type is not characterized by large burned-over areas that have failed to restock. Overstocking following fire in an uncut stand is more the rule, in fact, than

the exception. The few fail areas that do exist present individual problems and, as such, must be studied locally. Studies of the case history type and small test plots on these areas will produce valuable information.

For planting, 2-1 transplant stock is believed to be best for Intermountain conditions (41). It is certain that planting will be expensive. Current cost of 2-1 transplants at the Bend Nursery in Oregon is $14.31 per thousand. Labor, supervision, and other costs may amount to $45 per thousand.

Successful spot seeding on a lodgepole pine clear cutting in Montana was recently accomplished when accompanied by rodent poisoning (57). This method while cheaper than planting must be tested further, however, before it can be widely applied.

Because little seeding and planting has been done in this region an excellent starting point in regeneration research would be a study of the lodgepole stands of the region to establish seed collection zones and to determine and map the location of seed trees with desirable hereditary characteristics. This could be done along the lines suggested by Fowells (25) and Lindquist (44a). Delineation of seed collection zones would assure the observance of the general principles of seed provenance and would simplify methods of keeping records for seed lots in future regeneration and forest genetics research. Determination of genetically superior trees and their location would be a logical first step in the procurement of better seed for artificial reforestation.

Results of seed studies described under the subject "Silvics" will prove useful in seeding and planting tests in this region.

PART IV

SUGGESTED RESEARCH PROGRAM

This section presents a list and description of some of the short- and long-term studies deemed necessary to solve the more important problems discussed in the foregoing analysis. The studies are believed to be in order of priority. The intent in priority rating is merely to suggest the relative order in which the studies should be initiated based on the appraisal of present needs. A review of this order will be necessary from time to time to assure that current needs of national forest administration are being met and that all studies fit the overall scheme of lodgepole pine management in the Intermountain region.

The list does not include studies which fall outside the scope of forest management research. Their omission, however, does not minimize their importance. As noted in the analysis, for example, when funds allow for the initiation of utilization and economics research, the recommendations outlined therein can be used to guide work in these two important fields.

List of Studies

1. Stand structure survey of lodgepole pine--short-term study. (Includes field check of preliminary stand classification.)

   Object: To determine stand structure and composition, and obtain preliminary estimates of growth.

   Method: By sampling selected stands for total stems and species and to obtain a record of growth by borings.

2. The effect of intensity of post-cutting stand treatment on yield--short-term study.

   Object: To develop guides for use of stand improvement funds.

   Method: Application of different intensities of stand improvement and determination of effects on yield and stand condition.

3. Suitability and adaptability of volume tables--short-term study.

   Object: Determination of suitability of existing volume tables to Intermountain forest conditions.

   Method: Application of standard methods of checking volume tables using trees and stands not represented in original basic data.

4. Growth of thinned lodgepole pine--short-term study (plots already installed).

Object: To determine effects of different degrees of thinning in young and immature even-aged stands of lodgepole pine.

Method: Analysis of existing data from plots established on the Targhee National Forest by Administration.

5. Availability of lodgepole pine seed from logging slash after cutting--short-term study.

Object: To develop slash disposal criteria for maximum germination of seed after logging.

Method: Cone collection from slash and followup viability tests or seedling count after slash treatment.

6. Thinning for small products--long-term study.

Object: To determine yield and subsequent growth from different intensities of thinning in thrifty, immature lodgepole pine.

Method: Establishment and measurement of replicated study plots.

7. Construction of a weight-volume table for the Wasatch National Forest--short-term study.

Object: To provide a needed working tool for use in selling converter poles.

Method: By determining total cubic-foot contents and weights of representative samples of trees of different diameters and heights to a fixed top diameter outside bark.

8. Climatic loss and damage in lodgepole pine as related to tree height, bole diameter, and certain crown characteristics--long-term study.

Object: Development of height-diameter-crown criteria for use in marking for intermediate cuts.

Method: Multiple correlation analysis of data obtained from recent windfalls and damaged trees.

9. Regional comparison of lodgepole pine--short-term study.

Object: To determine specific physical and biological pecularities of lodgepole pine in different localities within each region.

Method: Comparisons of climate, soil, stand structure, composition, understory vegetation, and growth.

10. Thinning in stagnated sapling stands--long-term study.

Object: To determine the effect of heavy thinning on growth, form, and health of overstocked, stagnated sapling stands of pure lodgepole pine.

Method: Establishment and measurement of replicated study plots.

11. Growth performance of seedlings from different seed sources--short-term study.

Object: To determine desirable areas for seed collection preparatory to the development of a scheme for delineating seed collection zones.

Method: Collection of seed and comparison of seed germination and seedling growth.

12. Field tests of seed from different seed sources--long-term study.

Object: To compare germination and growth of seedlings from seed of different sources when planted in six different localities in the region.

Method: Randomized block field plots on:

1. Ashley Forest, south side of Uinta Mountains, Utah.
2. Wasatch Forest, north side of Uinta Mountains, Utah.
3. Bridger Forest, west-central Wyoming.
4. Targhee Forest, southeastern Idaho.
5. Salmon Forest, central Idaho.
6. Sawtooth Forest, south-central Idaho.

13. Field planting of lodgepole pine x jack pine hybrids on burned-over fail areas--short-term study.

Object: To test the suitability of lodgepole pine x jack pine hybrid stock for reforestation of burns that have failed to come back in lodgepole pine.

Method: Replicated study plots using lodgepole pine stock for control.

14. Study of regeneration fail areas--short-term study.

Object: To determine the causes for natural regeneration failures on cutover and burned-over areas.

Method: Surveys of individual fail areas and comparisons with areas where similar cutting practices or fires have resulted in restocking.

15. Economic study of pruning--short-term study.

Object: To show justification of pruning, if any, in lodgepole pine.

Method: Pruning thrifty, young lodgepole pine on good sites and analysis of projected costs and returns.

LITERATURE CITED

(1) ANONYMOUS
1949. Results of thinning lodgepole pine. Timberman 50(6): 112, 114.

(2) BAKER, F. S.
1934. Theory and practice of silviculture. 502 pp. McGraw-Hill Book Company, Inc., New York, illus.

(3) BARNES, GEORGE H.
1929. The development of even-aged stands of lodgepole pine in British Columbia. Thesis (MS) Univ. of Calif., Berkeley, Calif., 22 pp.

(4) BATES, C. G.
1912. Silvicultural systems of management of the central Rocky Mountain region. Soc. Amer. Foresters Proc. 7: 106-116.

(5) _____
1917. The biology of lodgepole pine as revealed by the behavior of its seed. Jour. Forestry 15: 410-416.

(6) _____
1923. Physiological requirements of Rocky Mountain trees. Jour. Agr. Res. 24: 97-164.

(7) _____
1924. Forest types in the central Rocky Mountains as affected by climate and soil. U. S. Dept. Agr. Bul. 1233, 152 pp., illus.

(8) _____
1925. The relative light requirements of some coniferous seedlings. Jour. Forestry 23: 869-879.

(9) _____
1930. The production, extraction and germination of lodgepole pine seed. U. S. Dept. Agr. Tech. Bul. 191, 92 pp., illus.

(10) _____, HILTON, H. C., and KRUEGER, T.
1928. Experiments in the silvicultural control of natural reproduction of lodgepole pine in the central Rocky Mountains. Jour. Agr. Res. 38: 229-243, illus.

(11) _____, and ROESER, J., JR.
1928. Light intensities required for growth of coniferous seedlings. Amer. Jour. Bot. 15: 185-194.

(12) BOE, KENNETH N.
1951. Progress report. RS-NRM, Silviculture, Harvest Cuttings, Lodgepole Pine, White Sulfur Springs Plots 1600-1603 (unpaged, 22 pp.) U. S. Forest Serv., North. Rocky Mountain Forest and Range Expt. Sta., Missoula, Mont.

(13) _____
1951. Natural regeneration of lodgepole pine on seedbeds created by clear cutting and slash disposal, U. S. Forest Serv., North. Rocky Mountain Forest and Range Expt. Sta. Research Note 99, 1 p., Missoula, Mont.

(14) CANDY, R. H.
1951. Reproduction on cut-over and burned-over land in Canada. Canada Dept. Resources and Development, Forest Research Div. Silvicultural Research Note No. 92, 224 pp. Ottawa.

(15) CLEMENTS, F. E.
1910. Life history of lodgepole burn forests. U. S. Forest Serv. Bul. 79, 56 pp., illus.

(16) CROSSLEY, D. I.
1950. Chemical thinning of young stagnating lodgepole pine stands. Canada Dept. Resources and Development, Forestry Branch. Silvicultural Leaflet No. 42, 2 pp. Ottawa.

(17) _____
1952. Some observations on lodgepole pine regeneration after clear cutting in strips. Canada Dept. Resources and Development, Div. Forest Research. Silvicultural Leaflet No. 65, 4 pp. Ottawa.

(18) _____
1952. Discing in overdense lodgepole pine reproduction. Canada Dept. Resources and Development, Div. Forest Research. Silvicultural Leaflet No. 66, 3 pp. Ottawa.

(19) CURTIS, JAMES D.
1949. A problem analysis for forest management research in the Intermountain region. U. S. Forest Serv., Intermountain Forest and Range Expt. Sta., 45 pp., Ogden, Utah.

(20) DAVIS, E. M.
1950. Wood utilization in Region 4 - a problem analysis. Office report, 18 pp. U. S. Dept. Agr. Forest Products Lab., Madison, Wis.

(21) DUNNEWALD, T. J.
1934. Soil factors in the failure of lodgepole pine plantings. Amer. Soc. Agron. Jour. 26: 586-591.

(22) EVENDEN, JAMES C., BEDARD, W. D., and STRUBLE, G. R.
1943. The mountain pine beetle, an important enemy of western pines. U. S. Dept. Agr. Circ. 664, 25 pp., illus.

(23) _____, and GIBSON, A. L.
1940. A destructive infestation in lodgepole pine stands by the mountain pine beetle. Jour. Forestry 38: 271-275.

(24) FLINT, H. R.
1924. Various aspects of the insect problem in the lodgepole pine region. U. S. Forest Serv., North. Rocky Mountain Forest and Range Expt. Sta. Applied Forestry Notes 54, 4 pp., Missoula, Mont.

(25) FOWELLS, H. A.
1946. Forest tree seed collection zones in California. U. S. Forest Serv., California Forest and Range Expt. Sta. Research Note No. 51. 5 pp., illus., Berkeley, Calif.

(26) GAIL, F. W., and LONG, E. M.
1935. A study of site, root development and transpiration in relation to the distribution of Pinus contorta. Ecology 16: 88-100, illus.

(27) GILL, LAKE S.
1952. A new host for Septogloeum gillii. The Plant Disease Reporter 36(7): 300.

(28) GOODELL, B. C.
1952. Watershed management aspects of thinned young lodgepole pine stands. Jour. Forestry 50: 374-378, illus.

(29) HAASIS, F. W., and THRUPP, A. C.
1931. Temperature relations of lodgepole pine seed germination. Ecology 12: 728-744.

(30) HODSON, E. R.
1908. Silvical notes on lodgepole pine. Soc. Amer. Foresters Proc. 3: 82-89.

(31) _____
1909. Early cuttings in the lodgepole pine type of Rocky Mountains. Conservation 15(3): 148-151, illus.

(32) HOPPING, GEORGE R.
1946. The lodgepole pine needle miner in western Canadian parks. Canada Dept. Agr., Div. Ent. Proc. Pub. 59, 3 pp.

(33) HOPPING, GEORGE R.
1950. Timber types in relation to insect outbreaks in the Canadian Rocky Mountains. Canada Dept. Agr., Div. Ent., Sci. Serv., Contribution No. 2757, Eighty-first annual report of the Ent. Soc. of Ontario. pp. 72-75., Ottawa.

(34) _____, and BEALL, GEOFFREY
1948. The relation of diameter of lodgepole pine to incidence of attack by the bark beetle Dendroctonus monticolae, Hopk. Forestry Chron. 24: 141-145.

(35) HORNIBROOK, E. M.
1940. Completion report: yield of selectively cut lodgepole pine in Colorado and Wyoming. U. S. Forest Serv., Rocky Mountain Forest and Range Expt. Sta., Office report, 44 pp., Ft. Collins, Colo.

(36) _____
1948. Cubic foot volume table for lodgepole pine. U. S. Forest Serv., Rocky Mountain Forest and Range Expt. Sta. Research Note 4, 3 pp., Ft. Collins, Colo.

(37) _____
1950. Estimating defect in mature and overmature stands of three Rocky Mountain conifers. Jour. Forestry 48: 408-417.

(38) JEWESSON, R. C., and DANYLUK, W.
1951. The comparative viability of seeds from different parts of the cones of interior Douglas-fir and lodgepole pine. UBC Forest Club, Research Committee, Research Note 4, 4 pp., Univ. Brit. Columbia, Vancouver, B. C.

(39) KEENE, W. L.
n. d. Thinning of lodgepole pine sapling stands for release. U. S. Forest Serv., Region 4, 3 pp. mimeo., Ogden, Utah.

(40) _____
1933. Thinning in lodgepole pine stands. In U. S. Forest Serv., Stand improvement in the regions of the U. S. 10 pp.

(41) KORSTIAN, C. F., and BAKER, F. S.
1925. Forest planting in the Intermountain region. U. S. Dept. Agr. Bul. 1264, 56 pp., illus.

(42) KOZIOL, F. C., ASTLE, W. S., and MILLER, J. M.
1935. Handbook for timber stand improvement and cleanup of roadside strips. Lodgepole pine section, pp. 9-11, U. S. Forest Serv., Ogden, Utah 29 pp., mimeo.

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EXPERIMENT STATION

(43) LEBARRON, R. K.
1952. Silvicultural practices for lodgepole pine in Montana. U. S. Forest Serv., North. Rocky Mountain Forest and Range Expt. Sta., Station Paper No. 33, 19 pp., Missoula, Mont.

(44) LEXEN, BERT
1949. Alternate clear-strip cutting in the lodgepole pine type. U. S. Forest Serv., Rocky Mountain Forest and Range Expt. Sta., Station Paper 1, 20 pp., Ft. Collins, Colo.

(44a) LINDQUIST, BERTIL
1948. Genetics in Swedish forestry practice. 173 pp. The Chronica Botanica Co., Waltham, Mass., illus. (Printed in Sweden)

(45) LONGYEAR, B. O.
1908. The formation of lodgepole pine forests. Forestry and Irrig. 10: 503-511.

(46) MAKI, T. EWALD
1939. Lodgepole pine silviculture - a project problem analysis. U. S. Forest Serv., Intermountain Forest and Range Expt. Sta., 15 pp., Ogden, Utah

(47) MASON, D. T.
1915. The life history of lodgepole pine in the Rocky Mountains. U. S. Dept. Agr. Bul. 154, 35 pp., illus.

(48) _____
1915. Utilization and management of lodgepole pine in the Rocky Mountains. U. S. Dept. Agr. Bul. 234, 54 pp., illus.

(49) _____
1915. Brush disposal in lodgepole pine cuttings. Soc. Amer. Foresters Proc. 10: 399-404.

(50) MOWAT, E. L.
1949. Preliminary guides for the management of lodgepole pine in Oregon and Washington. U. S. Forest Serv., Pacific Northwest Forest and Range Expt. Sta. Research Note 54, 10 pp., Portland, Ore.

(51) MUNGER, T. T.
1908. Report on the study of encroachment of lodgepole pine on western yellow pine on the east slopes of the Cascade Mountains in Oregon. U. S. Forest Serv., Pacific Northwest Forest and Range Experiment Station, 89 pp. (MS) Portland, Ore.

(52) _____
1914. Replacement of yellow pine by lodgepole pine on the pumice soils of central Oregon. Soc. Amer. Foresters Proc. 9: 396-406.

(53) ORR, L. W.
1952. Forest insect conditions in the Intermountain region in 1951. Office report, U. S. Bur. Ent. and Plant Quar., 11 pp., mimeo. Ogden, Utah.

(54) PATTERSON, J. E.
1930. Control of the mountain pine beetle in lodgepole pine by the use of solar heat. U. S. Dept. Agr. Tech. Bul. 195, 20 pp., illus.

(55) QUAITE, J.
1950. Severe thinning in an overstocked lodgepole pine stand. Canada Dept. Resources and Development. Dominion Forest Serv., Silvicultural Leaflet 47, 2 pp., Ottawa.

(56) QUINTUS, DICK
1951. Board foot volume table for lodgepole pine. Ore. State Board Forestry, Salem, Oregon. 2 pp.

(57) ROE, ARTHUR L., and BOE, KENNETH N.
1952. Spot seeding on a broadcast burned lodgepole pine clear cutting. U. S. Forest Serv., North. Rocky Mountain Forest and Range Expt. Sta. Research Note 108, 2 pp., Missoula, Mont.

(58) SOCIETY OF AMERICAN FORESTERS
1950. Forestry terminology. A glossary of technical terms used in forestry. Soc. Amer. Foresters, Washington, D. C. 93 pp.

(59) SUDWORTH, GEORGE G.
1917. The pine trees of the Rocky Mountain region. U. S. Dept. Agr. Bul. 460, 47 pp., illus. Lodgepole pine, pp. 38-42.

(60) TAYLOR, R. F.
1937. A tree classification for lodgepole pine in Colorado and Wyoming. Jour. Forestry 35: 868-875, illus.

(61) _____
1939. The application of a tree classification in marking lodgepole pine for selection cutting. Jour. Forestry 37: 777-782, illus.

(62) THOMPSON, M. W.
1929. Timber growing and cutting practice in the lodgepole pine region. U. S. Dept. Agr. Bul. 1499, 34 pp., illus.

(63) TILLOTSON, C. R.
1921. Storage of coniferous tree seed. Jour. Agr. Res. 22: 479-510.

(64) TRIMBLE, G. R., JR., and TRIPP, NORMAN R.
1948. Observations on the soils of the lodgepole pine forests. U. S. Forest Serv., North. Rocky Mountain Forest and Range Expt. Sta., Missoula, Mont. 7 pp. (MS)

(65) TRIPP, NORMAN R., and TRIMBLE, G. R., JR.
1949. Some effects of fire and cutting on forest soils in the lodgepole pine forests of the northern Rocky Mountains. Jour. Forestry 47: 640-642.

(66) UNITED STATES FOREST SERVICE
1922. Seed production of lodgepole pine (Pinus contorta, Loudon). North. Rocky Mountain Forest and Range Expt. Sta. Applied Forestry Notes 27, 1 p., Missoula, Mont.

(67) _____
1935. Annual report, 1934-1935. Intermount. Forest and Range Expt. Sta., 68 pp., Ogden, Utah.

(68) _____
1937. Annual investigative report. Intermount. Forest and Range Expt. Sta., 92 pp., Ogden, Utah.

(69) WEIR, JAMES R.
1916. Some suggestions on the control of dwarf mistletoe in the national forests of the Northwest. Forestry Quart. 14: 567-577.

(70) _____
1916. Mistletoe injury to conifers in the Northwest. U. S. Dept. Agr. Bul. 360, 39 pp., illus.

(71) _____
1918. Effect of mistletoe on young conifers. Jour. Agr. Res. 12: 715-718.

(72) WILM, H. G.
1943. Soil moisture under a coniferous forest. Trans. Amer. Geophys. Union. 24: 11-13.

(73) WOODHEAD, P. V.
1934. Thinning lodgepole pine in the central Rocky Mountain region. Jour. Forestry 32: 594-597.